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P. O. Box 7428 Seattle 33, Washington

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HARVEY MALICK
Calibration Section
IC & M Branch

MODEL 910A

TRUE RMS VOLTMETER

910A _____

910AR _____

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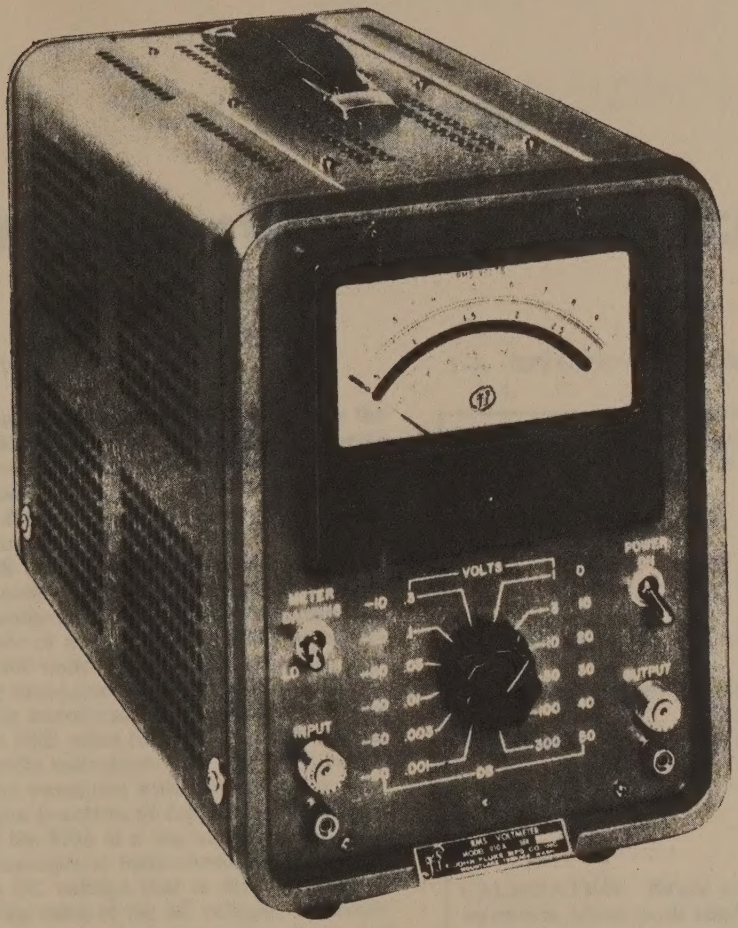

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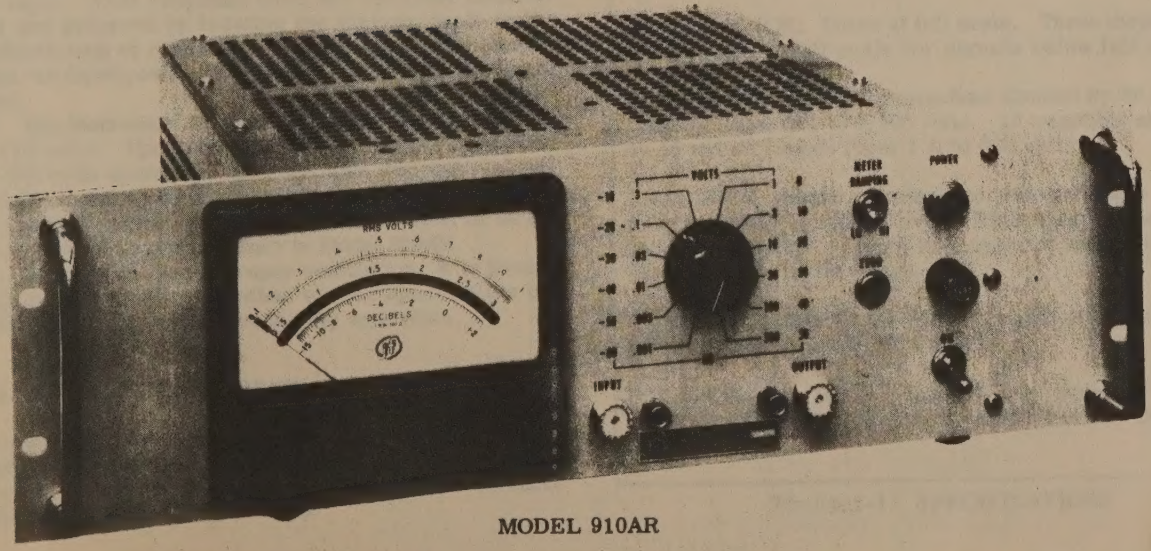

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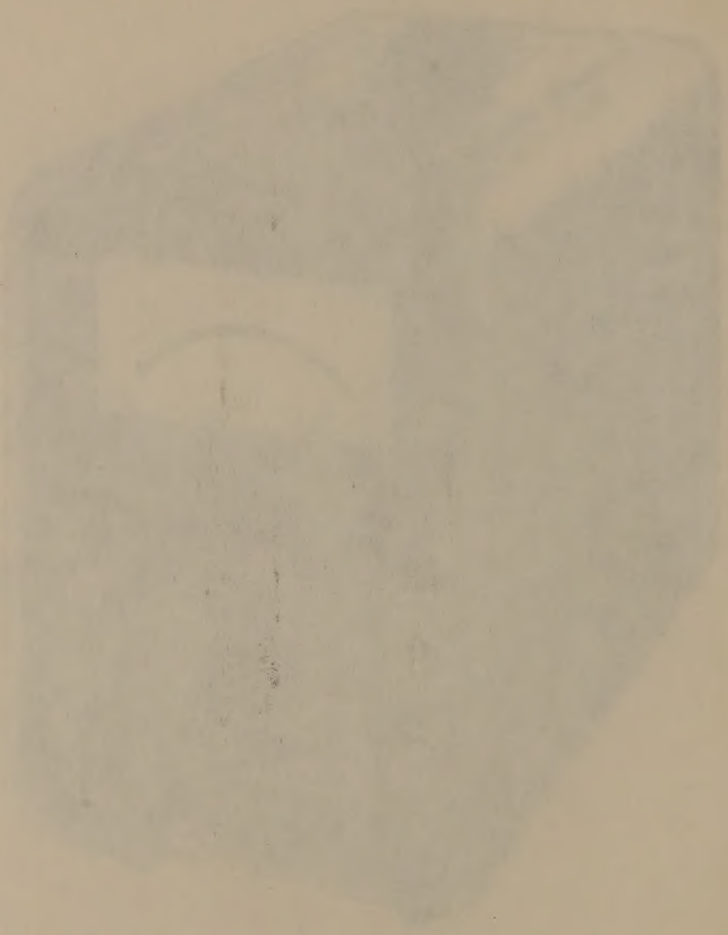


SECTION I

INTRODUCTION AND SPECIFICATIONS

1-1. INTRODUCTION

a. This instruction manual is intended for use with the Model 910A and Model 910AR RMS Voltmeters. Although essentially the same, the 910A is a cabinet model and the 910AR is a model designed to fit a standard 19" rack. Any other differences in the two instruments that affect this manual are so indicated.

b. The 910A RMS Voltmeter combines the ability to make true RMS measurements at high accuracy with extremely broad bandwidth. This RMS responding AC voltmeter is capable of measuring the RMS value between 0.0001 and 300 volts of any waveform with significant frequency components from 10 cps to 7 mc. The peak value of the waveform must be equal to or less than three times the RMS value for full scale indications. For less than full scale indications, the 910A will reveal the RMS value of any waveform with a crest factor up to three divided by the fraction of full scale indicated.

c. The nucleus of the 910A is a low impedance thermocouple. This thermocouple is instrumental in converting an AC voltage to a DC voltage that is directly related to the effective heating value of the AC voltage. A broadband AC amplifier provides high input impedance and high sensitivity while isolating the thermocouple from the input. Fast response time and accurate calibration are achieved by locating the thermocouple in the feedback loop of a sensitive DC amplifier which maintains the input power to the thermocouple at a constant level.

d. The instrument is normally supplied ready for use on 115 volts. Upon request, instruments are supplied for 230 volts operation. If it becomes desirable to convert from one mode of operation to the other, refer to the instruction decal on the back of Model 910A or on the top surface of the transformer in Model 910AR.

e. In order to insure proper ventilation, it is necessary to provide 2 or 3 inches of free space at the top and sides of the voltmeter during operation.

1-2. DAMAGE IN SHIPMENT

Immediately upon receipt, thoroughly inspect for any damage that may have occurred in transit. If any damage is noted, follow the instructions outlined on the warranty page at the back of this manual.

1-3. SPECIFICATIONS (MODELS 910A and 910AR)

VOLTAGE RANGE: 0.1 mv to 300 volts in twelve ranges with full scale readings of:

0.001	0.100	10.0
0.003	0.300	30.0
0.01	1.000	100.0
0.03	3.000	300.0

DECIBEL RANGE: -75 to +52 dbm in 12 ranges.

FREQUENCY RESPONSE: 10 cps to 7 mc.

ACCURACY:

±1%	of full scale	50 cps to 800 kc
±2%	" " "	20 cps to 2 mc
±3%	" " "	20 cps to 3.5 mc
±5%	" " "	10 cps to 7.0 mc

CALIBRATION: Reads root mean square value of any waveform whose peak amplitude is less than three times the RMS value and contains significant frequency components between 10 cps and 7.0 mc.

CREST FACTOR: Three at full scale. Three divided by the fraction of full scale for signals below full scale.

INPUT IMPEDANCE: 10 megohms shunted by 30 uuf on ranges from 0.001 to 0.300 volts. 10 megohms shunted by 15 uuf on ranges from 1.0 to 300 volts.

AMPLIFIER: Output terminals provide an output which is approximately 100 millivolts RMS at full scale, regardless of range. Output impedance is approximately 50 ohms over entire range.

POWER REQUIREMENTS: 115/230 volts ±10%, 50 to 60 cycles, approximately 80 watts.

SIZE: Cabinet: 10-1/2" high, 7-1/4" wide, 15" deep.
Rack: 5-1/2" high, 19" wide, 13-1/4" deep.

Figure 1-1. SPECIFICATIONS

SECTION II

OPERATING INSTRUCTIONS

2-1. CONTROLS, TERMINALS, AND INDICATORS

The location, circuit symbol, and a functional description of external controls, terminals, and indicators on the 910A RMS Voltmeter may be found in figure 2-1.

CONTROLS INDICATORS AND TERMINALS	LOCATION	CIRCUIT SYMBOL	FUNCTIONAL DESCRIPTION
INPUT terminals	Front panel	None	The AC voltage to be measured is applied to these terminals through banana plugs, a UHF connector, or a dual banana plug with 3/4 inch spacing. The banana jack and the UHF connector shell are connected to the chassis ground. The UHF connector center conductor is connected to the input network through a blocking capacitor. This allows the AC voltage to contain up to a 600 volt DC component.
OUTPUT terminals	Front panel	None	These terminals are provided for monitoring the waveform with an oscilloscope when measuring voltage or for using the instrument as a broadband amplifier. Regardless of the range selected, the output is approximately 100 mv RMS with a full scale meter reading. Output impedance is approximately 50 ohms over the entire range.
POWER toggle switch	Front panel	S1	Applies AC line voltage to the primary circuit of the power transformer.
Pilot light	Front panel	DS1	With the power switch on the red pilot lamp will illuminate.
VOLTS-DB range switch	Front panel	S2	Selects desired voltage or db range. The position of the switch indicates either full scale voltage of range in use or db level to be added algebraically to the meter indication on DECIBELS scale.
METER DAMPING toggle switch	Front panel	S3	Increases meter damping when placed in HI. High damping may be used whenever additional meter damping is desired, such as in noise measurements or for frequencies below 20 cps.

Figure 2-1. CONTROLS, TERMINALS, AND INDICATORS (Sheet 1 of 2)

CONTROLS INDICATORS AND TERMINALS	LOCATION	CIRCUIT SYMBOL	FUNCTIONAL DESCRIPTION
Meter	Front panel	M1	When the voltage range used contains the integer "1," use 0 to 1 scale. When the voltage range used contains the integer "3," use 0 to 3 scale. For db measurements use the red DECIBELS scale.
Mechanical zero control	Meter case	None	Sets meter to zero mechanically. This adjustment should be used only after instrument has been turned off for at least 15 minutes or when meter terminals have been shorted.
Electronic zero control	Back panel of 910A and Front panel of 910AR	R67	Sets meter to zero electronically. As long as meter needle is within the green zero area, no adjustment is required to make measurements within the specified accuracy. However, long time periods or drastic ambient temperature changes may cause the pointer to move away from zero. Do not use this control to compensate for misadjustment of mechanical zero control.
Fuse	Back panel of 910A and Front panel of 910AR	F1	Fuse holder protrudes from back of instrument to provide easy access to the fuse.

Figure 2-1. CONTROLS, TERMINALS, AND INDICATORS (Sheet 2 of 2)

2-2. PRELIMINARY OPERATION

The following procedure prepares the voltmeter for operation.

a. Connect power plug to 115 volt AC power source. If instrument has been wired for 230 volt operation, connect to 230 volts AC.

CAUTION

The round pin on polarized three-prong plug connects instrument case to power system ground. Use three-to-two pin adapter supplied with instrument when connecting to a two-contact receptacle. For personnel safety, connect short lead to a suitable ground.

b. Turn VOLTS-DB range switch to 300 volts.

c. Set POWER switch to ON. Red pilot lamp will illuminate. With no voltage connected to input, meter pointer may indicate full scale or above. Pointer should settle back to zero after 30 to 45 seconds warmup.

d. After a five-to-ten minute warmup period, check to see if pointer is in green zero area. If not, adjust electronic zero control to bring pointer into green zero area. The instrument is now ready for use.

2-3. VOLTAGE MEASUREMENTS

a. After completing preliminary operation, set range switch to desired position. On the high sensitivity ranges (1, 3, and 10 mv), part or full scale deflection may occur due to AC pickup from outside the instrument. This is normal and will not effect the meter reading. However, check meter zero by shorting out input or by turning range switch to 300 volts.

b. Connect voltage to be measured to INPUT terminals. The DC component of the voltage should not exceed 600 volts.

c. Read voltage indicated on meter. Use 0 to 1 scale when voltage range used contains the integer "1." Use 0 to 3 scale when voltage range used contains the integer "3."

2-4. DECIBEL MEASUREMENTS

Decibel measurements are made in the same way as voltage measurements except that the results are read on red DECIBELS scale. The actual level in decibels is the algebraic sum of the meter indication and the range switch DB position.

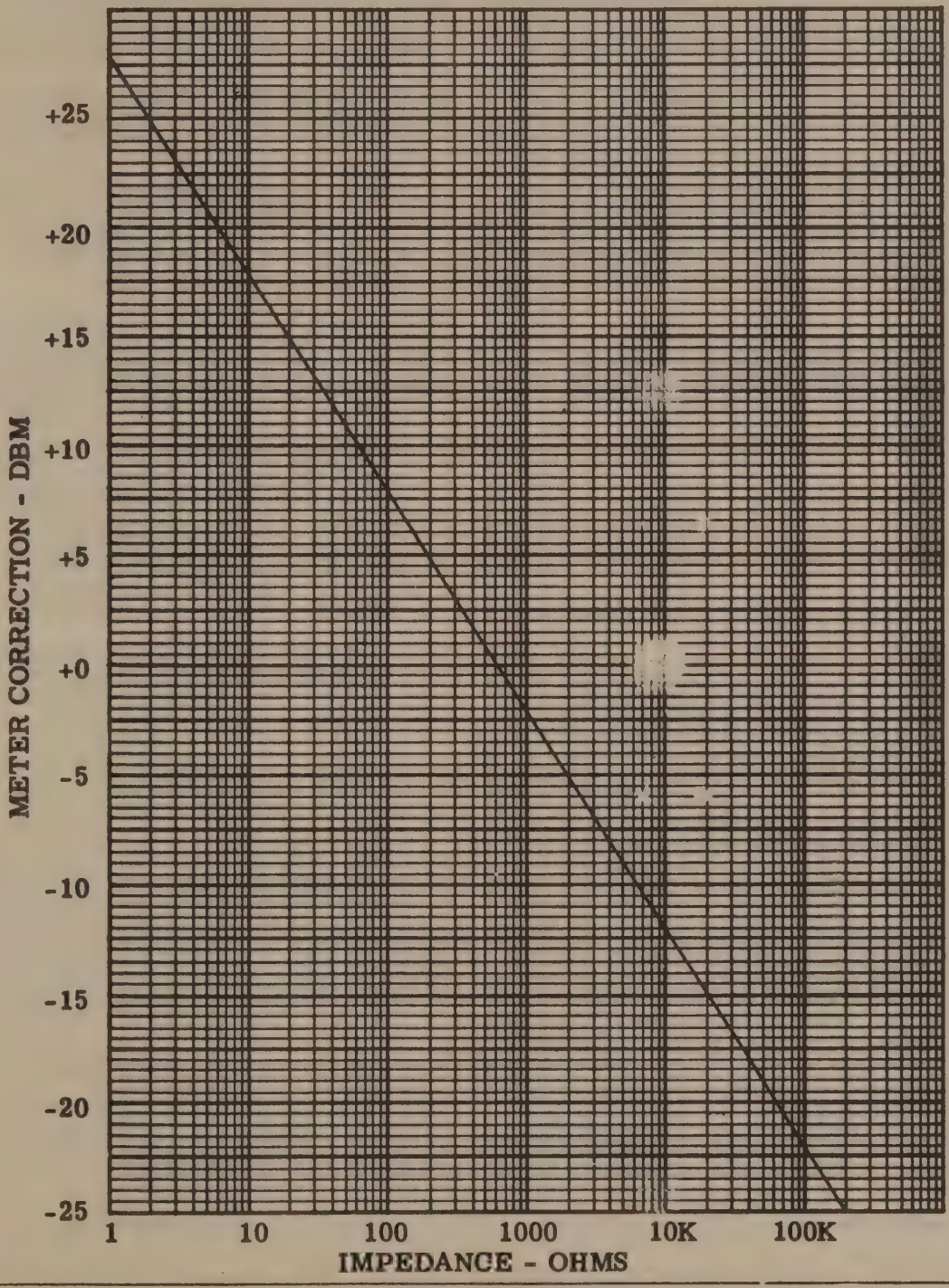


Figure 2-2. IMPEDANCE CORRECTION GRAPH

a. INDIVIDUAL MEASUREMENTS. The DECIBELS scale is calibrated so that zero dbm is equal to one milliwatt into a 600 ohm load.

(1) Complete steps "a" and "b" under voltage measurements.

(2) If measuring across 600 ohms, dbm level is found by algebraically adding meter DECIBELS indication to range switch DB position.

Example: Assume range switch is at +30 DB and meter indicates +1 DECIBELS.

Range position	+30
Meter indication	+ 1
Actual level	+31

(3) If measuring across impedances other than 600 ohms, meter correction graph (figure 2-2) must be used. The dbm level is found by algebraically adding meter DECIBELS indication and range switch DB position to correction factor shown on graph.

Example one: Assume range switch is at +30 DB, measurement is across 300 ohms, and meter indicates +2 DECIBELS.

Range position	+30
Meter indication	+ 2
Indicated dbm level	+32
Correction for 300 ohms	+ 3
Actual level	+35 dbm

Example two: Assume range switch is at +20 DB, measurement is across 5,000 ohms, and indicates -2 DECIBELS.

Range position	+20
Meter indication	- 2
Indicated dbm level	+18
Correction for 5,000 ohms	- 9.2
Actual level	+ 8.8 dbm

b. COMPARATIVE DB MEASUREMENTS. To find the power loss of a network or a line section or the power gain of an amplifier, complete the following steps.

(1) Complete individual measurements as outlined in paragraph 2-4a for each measurement to be compared.

(2) To find the db difference, algebraically subtract actual dbm level for second measurement from actual dbm level for first measurement.

2-5. USE OF AMPLIFIER

The instrument may be used simultaneously as a voltmeter and as an amplifier. Approximately 100 mv RMS is available at the output terminals at full scale meter deflection, regardless of range. The output impedance for oscilloscope monitoring or amplification function is 50 ohms over the entire frequency range.

a. After completing preliminary operation (paragraph 2-2), set range to desired position.

b. Connect voltage to be amplified to INPUT terminals.

c. Connect OUTPUT terminals to instrument that is to receive amplified signal.

d. The calibration of the 910A may be affected (especially at both ends of frequency band) if a low impedance is connected to the OUTPUT terminals. Check for this by monitoring meter while removing and replacing load at OUTPUT terminals. If meter reading changes, the load is affecting the calibration of the instrument.

NOTE

To prevent coupling between input and output terminals, it is recommended that shielded leads be used on high sensitivity ranges (1, 3, and 10 mv).

2-6. NOTES ON VOLTAGE AND DECIBEL MEASUREMENTS

a. When making prolonged measurements, allow 10 to 15 minutes warmup time to insure that the meter zero does not shift during the final warmup phase.

b. Crest factors can be determined by observing the voltage being measured on an oscilloscope connected to the OUTPUT terminals.

c. In certain environments, shielded leads must be used to prevent prohibitively high AC pickup on the most sensitive ranges.

d. Ground loop currents should be avoided to assure accuracy when making measurements. Potential differences are often found at different points on power system grounds. When this is the case, current may flow from the power system ground through the 910A and the equipment under measurement and back to the power system ground. To avoid this when system being measured is grounded, use three-wire line cord adapter on 910A power plug and do not connect short lead to ground.

e. To avoid short circuits when making voltage measurements, make certain that point to be connected to 910A INPUT chassis ground binding post has no potential with respect to chassis ground.

SECTION III

THEORY OF OPERATION

3-1. GENERAL

a. Figure 3-1 shows the block diagram for the 910A RMS Voltmeter. As seen in this figure, the circuit is composed of an input attenuator - cathode follower, a broadband AC amplifier, two thermocouples, a DC amplifier, and the power supplies. Refer to the schematic diagram following Section V to aid in the understanding of circuit theory and troubleshooting. This diagram is laid out such that signal flow is from left to right.

b. The overall operation of the voltmeter may be summarized as follows. After passing through a blocking capacitor, the unknown voltage is connected directly to a cathode follower on the six lower ranges. On the six upper ranges the unknown voltage is passed through a blocking capacitor and then reduced by a 1000 to 1 compensated voltage divider before being applied to the cathode follower. The cathode of the cathode follower is connected to a six position voltage divider which reduces the voltage to a maximum of 1 millivolt RMS. The voltage is then applied to a four-stage broadband AC amplifier. This amplifier delivers 3 ma RMS to the thermocouples for a full scale reading when 1 mv RMS is applied to the input of the amplifier. The thermocouples are arranged with a DC amplifier such that an input AC current will reduce an existing DC current by an amount related to the difference in their heating values. This reduction of DC current is indicated on the meter as the true RMS value of the input voltage.

c. In order to provide for a more complete understanding of the voltmeter, the following paragraphs describe each section of the circuit in detail.

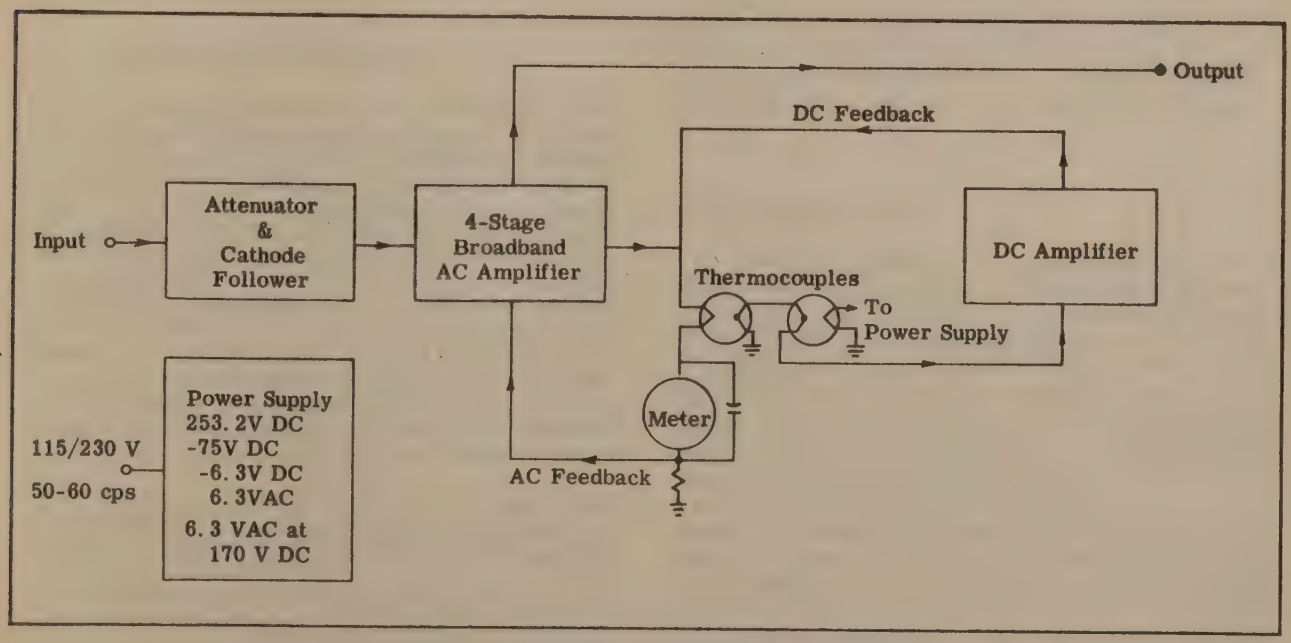


Figure 3-1. 910A RMS VOLTMETER BLOCK DIAGRAM

3-2. INPUT ATTENUATOR AND CATHODE FOLLOWER

a. The VOLTS-DB range switch (S2) is connected such that section S2A feeds the input voltage directly to the grid of V1 for the six lower ranges from 1 mv to 0.3 volts. For the six upper ranges from 1 to 300 volts, section S2A provides connection between the grid of V1 and the 1000 to 1 compensated voltage divider (R1 through R5 and C2 through C4) such that the input voltage is reduced by a factor of 1000 to 1.

b. For full scale deflection, 1 mv must be applied to the AC amplifier. The necessary reduction is provided by a six position voltage divider (R13 through R18) in the cathode circuit of V1. Section S2B of the range switch is connected to the six taps on the voltage divider. The movable segment of S2B has two arms each of which provide connection to the grid of V2 from one of the six taps. One arm is for the six lower ranges and the other is for the six upper ranges when the 1000 to 1 divider is operating. Thus twelve ranges are available because each tap serves two ranges.

c. Resistor R3 is provided for calibration of low frequency response and C2 is provided for calibration of high frequency response of the 1000 to 1 attenuator. On the .003 and 3 volt position, and the .01 and 1 volt position, an RC network is switched into the circuit to compensate for the high frequency response of the six position voltage divider. Capacitors C13 and C14 are provided for calibrating the two RC networks.

3-3. BROADBAND AC AMPLIFIER

a. The amplifier consists of four resistance-capacitance coupled voltage-amplifier stages. The plate, cathode, and grid circuits of each stage are designed such that negative feedback is combined with cathode degeneration and frequency compensating networks to provide high stability and a wide bandwidth. The high negative feedback makes the amplifier relatively insensitive to the gain changes in individual tubes due to aging and replacement. The feedback is returned from the plate of the last stage (V5) through the thermocouple to the cathode of the first stage (V2). This signal is 180 degrees out of phase with the signal appearing on the cathode of V2, thus decreasing the amplification. All these features help to provide the extremely wide frequency range (10 cps to 7 mc) over which the voltmeter may be used.

b. The gain of the circuit is adjusted by means of R38 in the feedback circuit. High frequency compensation is adjusted by means of C23 in the feedback circuit and R48 in the cathode circuit of V4.

c. The last stage of the AC amplifier (V5) acts as a cathode follower with respect to the OUTPUT terminals. The signal present at the output terminals is proportional to the voltage indicated on the meter and will be 100 mv RMS at no load for full scale deflection. The output impedance of the cathode follower is approximately 50 ohms.

3-4. THERMOCOUPLES AND DC AMPLIFIER

a. Thermocouples TC1 and TC2 are connected such that their outputs are opposing. With zero input voltage applied to the instrument, the temperature of TC1 is maintained by a quiescent plate current of approximately 5 ma from the plate of V6B. The temperature of TC2 is maintained such that the outputs of the two thermocouples are equal when zero voltage is supplied to the instrument. The 5 ma from the plate of V6B causes the entire B+ voltage to be dropped across the plate resistor R62 resulting in no potential across the meter.

b. With an input voltage connected to the instrument, the output of the AC amplifier passes through TC1. This increases the temperature of TC1 and thus increases its output voltage upsetting the balance between the outputs of the thermocouples. A DC amplifier is employed to amplify the DC potential difference. The difference is modulated by chopper contacts G1A and then the chopped voltage is stepped up by transformer T2. V6A, V7A, and V7B provide three stages of amplification before the signal is demodulated by chopper contacts G1B. The output of pentode V6B is then reduced by the demodulated signal. This reduction in plate current is related to the RMS value of the output current from the AC amplifier in such a way that the output of the thermocouples again comes into balance. Since the current through R62 can no longer be maintained by the DC plate current, a DC current must flow through the meter that is equal to the drop in DC plate current.

c. As mentioned before, 3 ma RMS is delivered to the thermocouple from the AC amplifier for full scale deflection. Since the DC amplifier maintains constant power into the thermocouple, the heating value of the AC amplifier and DC amplifier currents must be equal to the heating value of the DC current with no input. Thus, $I_{ac}^2 + I_{dc}^2 = 5\ ma^2$, or the new value of DC current must be $I_{dc} = (5\ ma^2 - 3\ ma^2)^{1/2} = 4$ ma. Finally, the meter current must be 5 ma - 4 ma or 1 ma for full scale deflection.

3-5. POWER SUPPLY

a. The power supply circuits provide an extremely stable regulated voltage supply for the cathode follower, AC amplifier, and DC amplifier. A regulated DC supply is used for the filament circuits of the cathode follower and video amplifiers to eliminate line transient effects. All other filament circuits are supplied from one of two unregulated 6.3 volt AC secondary power transformer windings. The primary winding is arranged such that the unit may be powered from either a 115 (±10%) or 230 (±10%) volt 50 to 60 cps power source.

b. A full wave rectifier system consisting of four diodes (CR1 through CR4) and a filter capacitor (C45A) supplies unregulated DC voltage for the 253.2 volt DC power supply. The voltage is regulated by comparing the voltage from reference tube V11 with a voltage tapped off a divider string (R104, R105, R106, and R107) in a differential amplifier V12. The output of differential amplifier V12 is fed to differential amplifier V13 which drives the grids of series passing tubes V9 and V10. In this way the B+ supply is maintained at 253.2 (±0.4) volts.

c. The unregulated -75 volt DC supply is obtained from a half-wave rectifier in series with the plate of pentode control tube V8. Reference string R83 and R84 is connected between B+ (253.2 volts) and the -75 volt output. The divider string supplies the control grid of V8 with approximately -2.5 volts. This control grid senses any change in the -75 volt supply in such a way that variations in the -75 volt DC unregulated supply become variation in the plate voltage of V8. The result is a highly stable -75 volt DC supply.

d. The 6.3 volt DC supply is obtained from a filtered full wave rectifier (CR5, CR6, and C43) which is regulated by a three transistor network (Q1, Q2, and Q3). A divider string (R86, R87, and R88) uses the B+ supply to obtain bias for Q3. To allow a higher collector resistance to be used, the collector of Q3 is powered from the -75 volt supply rather than the unregulated supply. The output of Q3 drives a Darlington connection of Q1 and Q2. Any variation in the unregulated -7.5 volt DC supply is subsequently sensed by the divider string changing the bias on Q3. This causes the current flowing through Q1 and hence Q2 to change in such a way that voltage variations are absorbed by Q2. The result is a highly stable, low ripple filament supply for the sensitive input attenuator and low level AC amplifier stages.

c. The filament supply for tubes V9, V10, V12, and V13 is taken from a 6.3 volt AC winding which is elevated in DC by the B+ voltage to insure that the 253.2 volt power supply tubes operate within their heater-cathode voltage rating. A separate 6.3 volt AC winding operated at ground potential supplies the filament voltage for tubes V5, V6, V7, and V8.

SECTION IV

MAINTENANCE

4-1. GENERAL

The 910A Voltmeter seldom requires any maintenance. There is no preventive maintenance of any sort. Without extreme abuse, all that should be required is occasional cleaning (for appearance only), tube replacement, and calibration. Paragraph 4-2 provides a discussion of troubleshooting and paragraph 4-3 delineates procedures necessary to calibrate the instrument. A troubleshooting chart, a servicing diagram, tube voltages and control location diagrams, a calibration equipment table, and component location diagrams are provided to aid in troubleshooting and calibration.

4-2. TROUBLESHOOTING

a. To assist in localizing most troubles which might occur, a troubleshooting chart (figure 4-1) lists the causes and remedies for a number of symptoms. If the cause of trouble cannot be found in this chart, apply 10 volts 400 cps to INPUT terminals and check for voltages shown on servicing diagram (figure 4-6) to localize the trouble. Sometimes it is useful to check the DC pin voltages on the tubes (figure 4-5) with a VTVM. No voltage should be connected to the INPUT terminals for this check. As an aid to troubleshooting, all components may be located by referring to figures 5-1 and 5-2. Furthermore, an understanding of the theory of operation (Section III) and frequent reference to the schematic diagram in the back of this manual will be of great value in troubleshooting.

b. As in most electronic instruments, failure of the 910A is usually due to tube failure. However, the 910A is conservatively designed and should require very infrequent tube replacement. (Tubes are rated at approxmately 10,000 hours). When tube replacement does become necessary, tubes with standard EIA (Electronic Industries Association) characteristics may be used. In order to avoid meter instability, tubes V1 and V2 should not be replaced with a microphonic or noisy tube. Such a tube, if otherwise satisfactory, may be interchanged with V3, V4, V5, or V8. Also, in rare cases, a microphonic 6AW8A may cause trouble when used for V6. If this occurs, it may be interchanged with V13.

c. Normally, replacement of tubes will not necessitate complete recalibration of the instrument. The B+ voltage should be checked as outlined in paragraph 4-3c if V11 or V12 is replaced. If V2, V3, V4, or V5 is replaced, check the high frequency response per paragraph 4-3g.

SYMPTOM	PROBABLE CAUSE	REMEDY
Instrument not operating. Pilot light not illuminated.	Blown line fuse.	Replace fuse.
	Defective line cord or POWER switch.	Check with ohmmeter. Repair or replace if defective.
Fuse blows when replaced.	Shorted diode.	Check CR1 through CR7.
	Shorted filter capacitor.	Check C43, C44, and C45A. Replace if defective.
	Defective power supply tube.	Check V8, V9, V10, V12, and V13 by replacement.
Meter indicates less than half scale and will not zero on any range.	Electronic zero misadjusted.	Recalibrate per paragraph 4-3b(5).
	Defective power supply.	Check +253.2 volt, -75 volt, and 63 volt supplies in that order.
	Defective AC Amplifier.	Check by removing V5. If meter returns to zero, check V2 through V5 by replacement.

Figure 4-1 TROUBLESHOOTING CHART (Sheet 1 of 2)

SYMPTOM	PROBABLE CAUSE	REMEDY
Meter pinned past full scale.	Defective AC amplifier.	Check by removing V5. If meter returns to zero, check V2 through V5 by replacement.
	Defective thermocouple.	Measure voltage at pin 9 of V6. If more than 4 volts, replace TC1.
	Defective DC amplifier.	Check V6 and V7 by substitution.
	Defective power supply.	Check 253.2 volt, -75 volt, and 6.3 volt supplies in that order.
Meter rattle or drift.	Defective power supply.	Check 253.2 volt, -75 volt, and 6.3 volt supplies in that order.
	Cathode follower input circuit defective.	If symptoms are reduced on 0.3 and 300 volt ranges, check V1 and C9.
	Defective AC amplifier.	Check V2 through V5 by replacement. Check voltage on each stage to locate defective stage.

Figure 4-1. TROUBLESHOOTING CHART (Sheet 2 of 2)

4-3. CALIBRATION

a. GENERAL. The 910A can be calibrated as often as deemed necessary. However, it is recommended that the instrument be calibrated every 60 days. This is a conservative estimate and as one becomes more familiar with the instrument, it will undoubtedly be found that calibration will be required at less frequent intervals. Figure 4-2 lists the type of test equipment required for calibration along with the applicable specifications and recommended instruments. All controls may be located with the aid of figures 4-3 and 4-4.

EQUIPMENT	RECOMMENDED INSTRUMENT	SPECIFICATIONS REQUIRED
Differential Voltmeter	Any John Fluke 800 series model Differential Voltmeter	Must be capable of measuring 253.2 volts with an accuracy of 0.10%
Voltmeter Calibrator	Hewlett-Packard 738A Voltmeter Calibrator	Must provide 0.01 and 1 volt at 400 cps with an accuracy of 0.25%
Oscillator	Hewlett-Packard 200S Oscillator	These two instruments together must be capable of producing a constant voltage of 0.001, 0.003, 0.01, and 1 volt at a frequency from 400 cps to 10 mc.
Frequency Response Test Set	Hewlett-Packard 739A Test Set	

Figure 4-2. CALIBRATION EQUIPMENT

b. PRELIMINARY PROCEDURES.

(1) Place 910A and all calibration test equipment in operation.

(2) Allow all equipment to warm up until it reaches equilibrium temperature (about 1/2 hour).

(3) If using Model 910A, remove both side panels. If using Model 910AR, remove top and bottom panels.

(4) Short terminals of 910A meter while adjusting mechanical zero control to zero meter.

(5) If meter indication is out of green zero area with the INPUT terminals shorted, and the range switch at 300 volts, adjust electronically as follows:

(a) Attempt adjustment by using electronic zero control.

(b) If meter cannot be zeroed by this means, center electronic zero control and adjust coarse electronic zero potentiometer R66 until meter is zeroed.

c. 253.2V DC POWER SUPPLY ADJUSTMENT.

(1) Measure B+ voltage between any terminating red wire and the 910A chassis with differential voltmeter.

(2) Adjust fine adjustment potentiometer R107 until voltage is 253.2 (±0.4) volts. If voltage is obtained, proceed to filament supply adjustment (paragraph 4-4d).

(3) If voltage adjustment cannot be made, center fine adjustment potentiometer R107.

(4) Adjust coarse adjustment potentiometer R106 for approximately 253.2 volts.

(5) Readjust R107 for 253.2 (±0.4) volts.

d. FILAMENT SUPPLY ADJUSTMENT.

(1) Measure -6.3 volt filament voltage at pin 4 of V2.

(2) Adjust -6.3 volt adjust potentiometer R86 for -6.3 (±0.1) volts.

e. 400 CYCLE CALIBRATION.

(1) Connect OUTPUT terminal of HP 738A Voltmeter Calibrator to INPUT terminal of 910A with a 52 ohm coaxial cable.

(2) Set range switch on 910A to 0.01 volts.

(3) Set voltmeter calibrator for an output of 0.01 volts at 400 cps RMS.

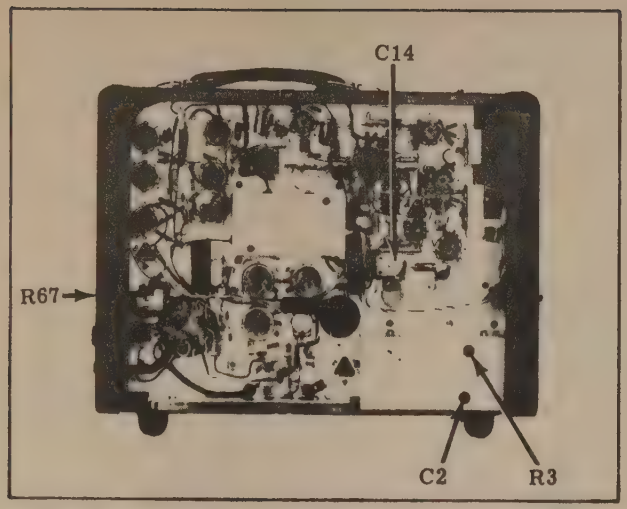


Figure 4-3. ADJUSTMENT LOCATIONS

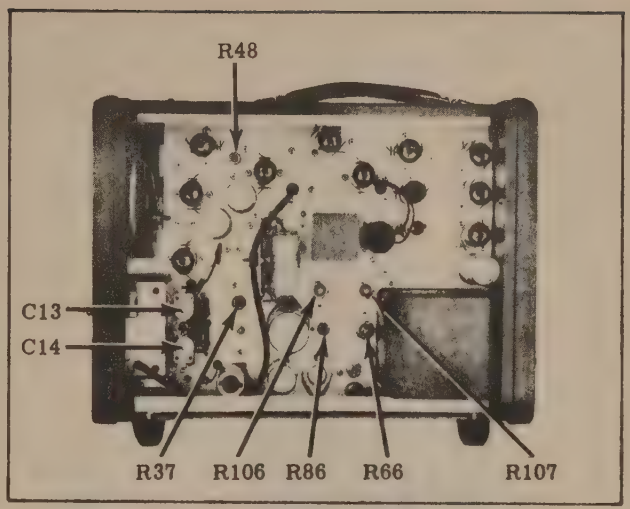


Figure 4-4. ADJUSTMENT LOCATIONS

Symbol & Type	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8	Pin 9
V1, 6EJ7	50	-	50	6.3	0	0	150	150	150
V2, 6EJ7	1.1	0	1.1	6.3	0	0	140	115	1.1
V3, 6EJ7	1.1	0	1.1	6.3	0	0	145	110	1.1
V4, 6EJ7	1.1	0	1.1	6.3	0	0	200	110	1.1
V5, 6EJ7	1.4	.35	1.4	6.3ac	0	0	140	110	1.4
V6, 6AW8A	.7	0	140	6.3ac	0	-75	-76.5	0	-7.5
V7, 12AX7	160	0	1.8	6.3ac	6.3ac	160	0	1.8	0
V8, 6EJ7	0	-2.5	0	6.3ac	0	0	70	253.2	0
V9, 12B4	254	251	Heater voltage 6.3 volts ac. 170 volts above ground.			No Conn.	251	No conn.	355
V10, 12B4	254	251				No Conn.	251	No Conn.	355
V11, OG3	85	0	84	0	85	No Conn.	0	No Pin	No Pin
V12, 12AX7	175	85	86	Heater voltage 6.3 volts ac 170 volts above ground		175	85	86	See Pin 4 & 5
V13, 6AW8A	180	175	253.2			180	175	253.2	250

This chart is to be used under the following conditions: (a) range switch on 300; (b) line voltage at 115V, 60 cycles; (c) no input voltage; (d) all measurements made with a VTVM; (e) all measurements made from ground to specified tube pin: (f) plate and screen voltage may vary up to ±20%.

Figure 4-5. TUBE VOLTAGE CHART

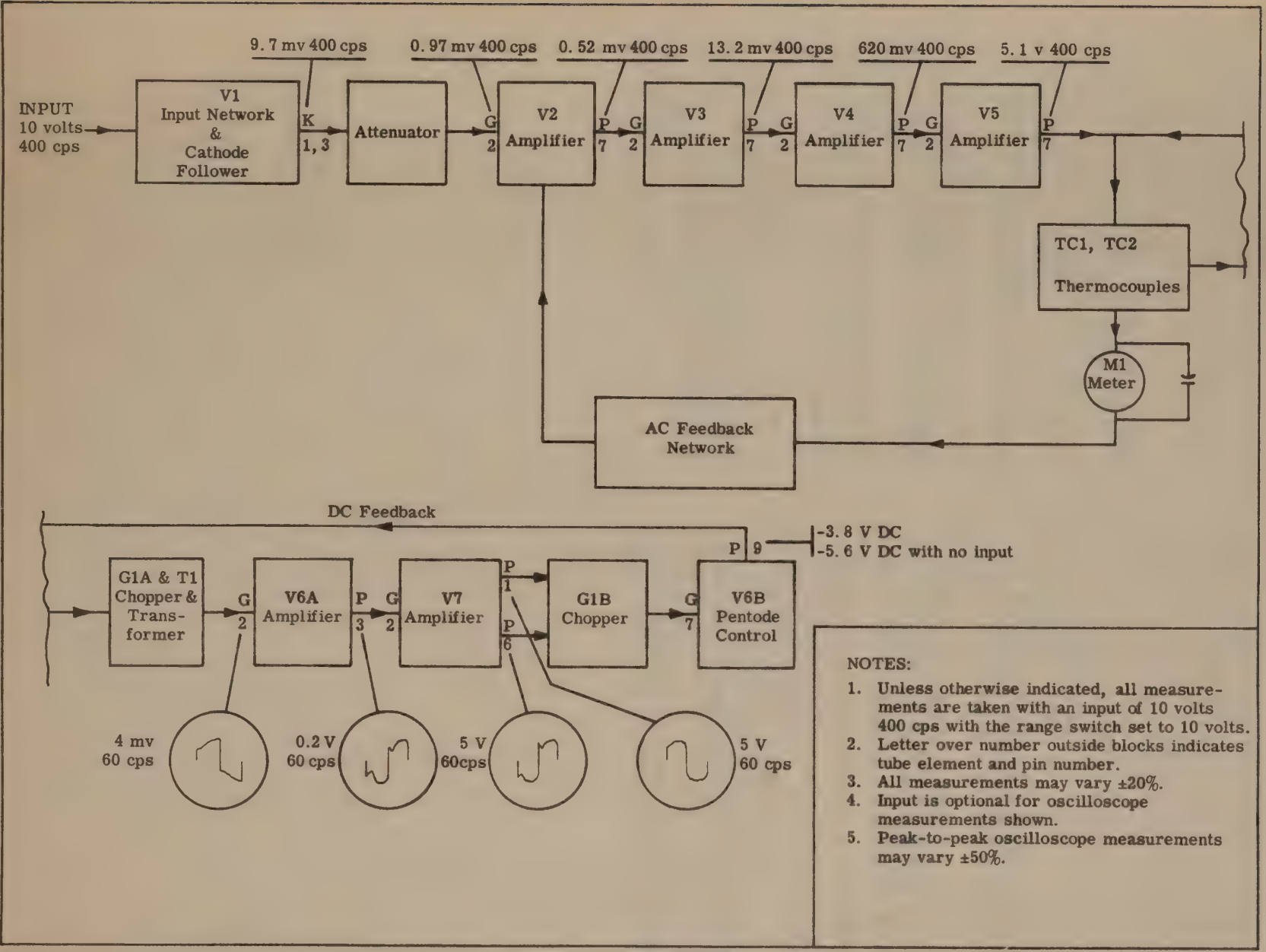


Figure 4-6. SERVICING DIAGRAM

(4) Adjust R37 until pointer comes to rest over the 1 on 0-1 scale of 910A.

(5) Set range switch on 910A to 1.0 volts.

(6) Set voltmeter calibrator for an output of 1.0 volt at 400 cycles.

(7) Adjust R3 until pointer comes to rest over the 1 on 0 to 1 scale of 910A.

(8) Disconnect voltmeter calibrator.

f. 20 KC CALIBRATION

(1) Connect a 50 ohm coaxial cable between OUTPUT terminal of HP 200S oscillator and EXTERNAL INPUT terminal of 739A Frequency Response Test Set.

(2) Connect 50 ohm terminated output cable provided with HP 739A between OUTPUT terminal of HP 739A and INPUT terminal of 910A.

(3) Set range switch on 910A to 1.0 volt.

(4) Set OUTPUT ATTENUATOR on frequency response test set to 1.0 volt.

(5) Set oscillator for 400 cycles and adjust its AMPLITUDE until 910A meter indicates 1.0 volt.

(6) Turn METER SET adjust on frequency response test set until pointer on test set meter is on SET LEVEL reference mark.

(7) Set oscillator for 20 kc and adjust its AMPLITUDE control until pointer on test set is again on SET LEVEL reference mark.

(8) Adjust C2 on 910A until 910A meter indicates 1.0 volt.

(9) Disconnect HP 200S Oscillator from test set.

g. 7 MC CALIBRATION

(1) Set OUTPUT ATTENUATOR on frequency response test set to 0.001 volt and set frequency dials for 300 kc.

(2) If using Model 910A, place side panels on instrument. If using Model 910AR, place top and bottom panels on instrument.

(3) Set 910A range switch to 0.001 volt.

(4) Adjust test set AMPLITUDE for 0 db as indicated on 910A meter.

(5) Set frequency controls on test set for 7 mc.

(6) Adjust high frequency compensation potentiometer R48 for 0 db as indicated on 910A meter.

(7) Set frequency controls on test set for 10 mc.

(8) Note indication on 910A meter. High frequency calibration is complete if response is down 0.2 to 0.5 db.

(9) If response is down less than 0.2 db or more than 0.5 db:

(a) Set frequency controls on test set for 7 mc.

(b) If response is down less than 0.2 db, turn R48 slightly counterclockwise.

(c) If response is down more than 0.5 db, turn R48 slightly clockwise.

(d) Adjust C23 for 0 db as indicated on 910A meter.

(e) Repeat steps (7) and (8) to check response. If necessary, repeat step (9) until desired response is obtained.

g. 0.003 VOLT RANGE CALIBRATION

(1) Set range switch on 910A to .003 volts.

(2) Set frequency response test set OUTPUT ATTENUATOR to .003 volts and set frequency controls for 300 kc.

(3) Adjust test set AMPLITUDE for 0 db as indicated on 910A meter.

(4) Set test set for 3 mc and adjust C13 for 0 db as indicated on 910A meter.

h. 0.01 VOLT RANGE CALIBRATION

(1) Set range switch on 910A to .01 volt.

(2) Set frequency response test set OUTPUT ATTENUATOR to 0.01 volt and set frequency controls for 300 kc.

(3) Adjust test set AMPLITUDE for 0 db as indicated on 910A meter.

(4) Set test set for 3 mc and adjust C14 for 0 db as indicated on 910A meter. The instrument is now calibrated.

SECTION V

LIST OF REPLACEABLE PARTS

The following list of replaceable parts covers the Model 910A and Model 910AR RMS Voltmeters. As time goes on, our engineers strive to improve the instrument in every way. For this reason, a "Use Code", last column, is provided to define the effectivity of each part. A list of all "Use Codes" and their effectivity is included at the end of this section.

REFERENCE DESIGNATION	DESCRIPTION	FLUKE STOCK NO.	USE CODE
C1	Capacitor, mylar, 0.047 uf, 20%, 600 V DC	CF40	
C2	Capacitor, ceramic, variable, 1.5-7 uuf, 500 V DC	CT24	
C3, C4	Capacitor, mica, 2500 uuf, 1%, 500 V DC	CM11	
C5	Capacitor, mylar, 0.047 uf, 20%, 100 V DC	CF38	
C6	Capacitor, electrolytic, 40 uf, -10/+100%, 250 V DC	CE42	
C7	Capacitor, mylar, 0.047 uf, 20%, 100 V DC	CF38	
C8	Capacitor, ceramic, 2.2 uf, -0%, 3 V DC	CT45	
C9	Capacitor, tantalum, 10 uf, -15/+20%, 60 V DC	CE53	
C10	Capacitor, ceramic, 62 uuf, 10%, 500 V DC	CT44	*
C11	Capacitor, ceramic, 20 uuf, 10%, 500 V DC	CT42	
C12	Capacitor, ceramic, 3.3 uuf, 10%, 500 V DC	CT43	
C13, C14	Capacitor, ceramic, variable, 7-45 uuf, 500 V DC	CT40	
C15 ABC	Capacitor, electrolytic, 20-40-20 uf, 250 V DC	CE66	
C16	Capacitor, ceramic, 27 uuf, 10%, 600 V DC	CT32	

REFERENCE DESIGNATION	DESCRIPTION	FLUKE STOCK NO.	USE CODE
R6	Resistor, composition, 390 Ω, 10%, 1/2W	EB3911	
R7	Resistor, composition, 6.8 Meg. 10%, 1/2W	EB6851	
R8	Resistor, composition, 2.2 Meg. 10%, 1/2W	EB2251	
R9	Resistor, precision metal film, 170 K, 1%, 1/2W	MR29	
R10	Resistor, precision metal film, 82 K, 1%, 1/2W	MR28	
R11	Resistor, composition, 8.2 K, 10%, 2 W	HB8221	
R12	Resistor, metal film, 6.8 K, 10%, 2 W	MR17	
R13	Resistor, precision wirewound, 3243.4 Ω, 0.1%, 1/10 W	PR651	
R14	Resistor, precision wirewound, 1025.66 Ω, 0.1%, 1/10 W	PR650	
R15	Resistor, precision wirewound, 324.34 Ω, 0.1%, 1/10 W	PR649	
R16	Resistor, precision wirewound, 102.566 Ω, 0.1%, 1/10 W	PR648	
R17	Resistor, precision wirewound, 32.434 Ω, 0.1%, 1/10 W	PR647	
R18	Resistor, precision wirewound, 15.000 Ω, 0.1%, 1/10 W	PR646	
R19	Resistor, composition, 300 Ω, 5%, 1/2 W	EB3015	*
R20	Resistor, composition, 220 Ω, 10%, 1/2 W	EB2211	*
R21	Resistor, composition, 47 Ω, 10%, 1/2 W	EB4701	
R22	Resistor, metal film, 39 K, 5%, 1 W	MR33	
R23	Resistor, metal film, 6.8 K, 10%, 2 W	MR17	
R24	Resistor, metal film, 3.9 K, 5%, 1 W	MR32	
R25	Resistor, metal film, 620 Ω, 5%, 1 W	MR31	
R26	Resistor, metal film, 75 Ω, 5%, 1 W	MR30	
R27	Resistor, composition, 820 K, 10%, 1/2 W	EB8241	
R28	Resistor, composition, 680 K, 10%, 1/2 W	EB6841	
R29	Resistor, composition, 47 Ω, 10%, 1/2 W	EB4701	

REFERENCE DESIGNATION	DESCRIPTION	FLUKE STOCK NO.	USE CODE
R30	Resistor, composition, 39 K, 10%, 1 W	GB3931	
R31	Resistor, composition, 680 K, 10%, 1/2 W	EB6841	
R32	Resistor, composition, 6.8 K, 10%, 2 W	HB6821	
R33	Resistor, composition, 3.9 K, 10%, 1 W	GB3921	
R34	Resistor, composition, 390 Ω, 10%, 1/2 W	EB3911	
R35	Resistor, composition, 82 Ω, 5%, 1/2 W	EB8205	
R36	Resistor, precision wirewound, 10 Ω, 0.5%, 0.075 microhenry, 10% (If replacement is required, it will be necessary to replace both R36 and R63 with ℳ No. 34-2062)	PR642	A
R36	Resistor, precision wirewound, 10 Ω, 0.5%, 0.075 microhenry, 10%	34-2062	B
R37	Resistor, composition, variable, 100 Ω, 20%, 1/2 W	P100	
R38	Resistor, composition, 56 Ω, 10%, 1/2 W	EB5601	
R39	Resistor, precision metal film, 270 Ω, 0.5%, 1/2 W	MR27	
R40	Resistor, composition, 2.2 Meg, 10%, 1/2 W	EB2251	
R41	Resistor, composition, 2.7 Meg, 10%, 1/2 W	EB2751	
R42	Resistor, composition, 47 Ω, 10%, 1/2 W	EB4701	
R43	Resistor, composition, 39 K, 10%, 1 W	GB3931	
R44	Resistor, composition, 820 K, 10%, 1/2 W	EB8241	
R45	Resistor, composition, 6.8 K, 10%, 2 W	HB6821	
R46	Resistor, composition, 1.2 K, 10%, 1/2 W	EB1221	
R47	Resistor, composition, 470 Ω, 10%, 1/2 W	EB4711	
R48	Resistor, composition, variable, 100 Ω, 20%, 1/2 W	P100	
R49	Resistor, composition, 2.2 Meg, 10%, 1/2 W	EB2251	
R50	Resistor, composition, 1.5 Meg, 10%, 1/2 W	EB1551	
R51	Resistor, composition, 47 Ω, 10%, 1/2 W	EB4701	
R52	Resistor, composition, 120 K, 10%, 1/2 W	EB1241	

REFERENCE DESIGNATION	DESCRIPTION	FLUKE STOCK NO.	USE CODE
R53	Resistor, composition, 39 K, 10%, 1 W	GB3931	
R54	Resistor, composition, 820 K, 10%, 1/2 W	EB8241	
R55	Resistor, composition, 15 K, 10%, 2 W	HB1531	
R56	Resistor, composition, 39 K, 10%, 1 W	GB3931	
R57	Resistor, composition, 82 Ω, 5%, 1/2 W	EB8205	
R58	Resistor, composition, 22 Ω, 10%, 1/2 W	EB2201	
R59	Resistor, composition, 27 Ω, 10%, 1/2 W	EB2701	
R60, R61	Resistor, composition, 680 Ω, 10%, 1/2 W	EB6811	
R62	Resistor, precision wirewound, 51 K, 0.05%, 2 W	PR518	
R63	Resistor, precision wirewound, 10 Ω, 0.5% 0.075 microhenry, 10% (If replacement is required, it will be necessary to replace both R36 and R63 with ℳ No. 34-2062).	PR642	A
R63	Resistor, precision wirewound, 10 Ω, 0.5% 0.075 microhenry, 10%	34-2062	B
R64	Resistor, composition, 1 K, 10%, 1/2 W	EB1021	
R65	Resistor, precision wirewound, 45 K, 0.5%, 2 W	PR523	
R66	Resistor, wirewound, variable, 10 K, 20%, 2 W	P10KA	
R67	Resistor, wirewound, variable, 500 Ω, 10%, 2 W	P500A	
R68	Resistor, composition, 68 K, 10%, 1/2 W	EB6831	
R69	Resistor, composition, 820 Ω, 10%, 1/2 W	EB8211	
R70	Resistor, composition, 1.5 Meg. 10%, 1/2 W	EB1551	
R71	Resistor, composition, 180 K, 10%, 1/2 W	EB1841	
R72	Resistor, composition, 100 K, 10%, 1/2 W	EB1041	
R73	Resistor, composition, 180 K, 10%, 1/2 W	EB1841	
R74, R75	Resistor, composition, 100 Ω, 10%, 1/2 W	EB1011	
R76, R77	Resistor, composition, 1 Meg. 10%, 1/2 W	EB1051	
R78	Resistor, composition, 22 K, 10%, 1/2 W	EB2231	

REFERENCE DESIGNATION	DESCRIPTION	FLUKE STOCK NO.	USE CODE
R79	Resistor, composition, 120 Ω, 10%, 1/2 W	EB1211	
R80	Resistor, composition, 100 Ω, 10%, 1/2 W	EB1011	
R81	Resistor, composition, 1 K, 10%, 1/2 W	EB1021	
R82	Resistor, composition, 120 Ω, 10%, 1/2 W	EB1211	
R83	Resistor, deposited carbon, 103.5 K, 1%, 1/2 W	DR63	
R84	Resistor, deposited carbon, 383 K, 1%, 1/2 W	DR804	
R85	Resistor, composition, 68 K, 10%, 1/2 W	EB6831	
R86	Resistor, composition, variable, 1 K, 30%, 3/10 W	P1K	
R87	Resistor, deposited carbon, 5 K, 1%, 1/2 W	DR49	
R88	Resistor, deposited carbon, 230 K, 1%, 1/2 W	DR612	
R89	Resistor, composition, 2.2 Meg. 10%, 1/2 W	EB2251	
R90	Resistor, composition, 1 Meg. 10%, 1/2 W	EB1051	
R91	Resistor, composition, 33 Ω, 10%, 1/2 W	EB3301	
R92	Resistor, composition, 470 Ω, 10%, 1/2 W	EB4711	
R93	Resistor, composition, 39 K, 10%, 1 W	GB3931	
R94	Resistor, composition, 100 K, 10%, 1/2 W	EB1041	
R95	Resistor, composition, 470 Ω, 10%, 1/2 W	EB4711	
R96	Resistor, composition, 33 Ω, 10%, 1/2 W	EB3301	
R97	Resistor, composition, 270 K, 10%, 1/2 W	EB2741	
R98	Resistor, composition, 330 K, 10%, 1/2 W	EB3341	
R99	Resistor, composition, 4.7 K, 10%, 1/2 W	EB4721	
R100	Resistor, composition, 68 K, 10%, 1 W	GB6831	
R101	Resistor, composition, 150 K, 10%, 1/2 W	EB1541	
R102	Resistor, composition, 270 K, 10%, 1/2 W	EB2741	
R103	Resistor, composition, 150 K, 10%, 1/2 W	EB1541	
R104	Resistor, precision metal film, 170 K, 1%, 1/2 W	MR29	

REFERENCE DESIGNATION	DESCRIPTION	FLUKE STOCK NO.	USE CODE
R105	Resistor, precision metal film, 82 K, 1%, 1/2 W	MR28	
R106	Resistor, wirewound, variable, 10 K, 20%, 2 W	P10KA	
R107	Resistor, wirewound, variable, 500 Ω, 10%, 2 W	P500A	
R108	Resistor, composition, 10 Ω, 10%, 1/2 W	EB1001	
S1	Switch, toggle, STSP	ST5	
S2	Switch, rotary, 12 position	910A-804	
S3	Switch, toggle, STSP	ST5	
TC1, TC2	Thermocouple, vacuum, 7.5 ma (a matched pair)	X2053	
T1	Transformer, power	910A-651	
T2	Transformer, instrument	910A-652	
V1 thru V5	Vacuum tube pentode, 6EJ7	6EJ7	
V6	Vacuum tube triode-pentode, 6AW8A	6AW8A	
V7	Vacuum tube duo triode, 12AX7	12AX7	
V8	Vacuum tube pentode, 6EJ7	6EJ7	
V9, V10	Vacuum tube power triode, 12B4A	12B4A	
V11	Vacuum tube voltage reference, 0G3	0G3	
V12	Vacuum tube duo triode, 12AX7	12AX7	
V13	Vacuum tube triode-pentode, 6AW8A	6AW8A	
	Binding post, ground, uninsulated	X407	
	Binding post cap, knurled	X407A	
	Clamp, tube	X445	
	Clamp, tube	X445A	
	Cord, power, 3 wire	X27H	
	Foot, nylon (rack model only)	X2063	
	Foot, rubber (cabinet model only)	X224	
	Fuse holder, Bayonet type	X12	

REFERENCE DESIGNATION	DESCRIPTION	FLUKE STOCK NO.	USE CODE
	Handle, flexible, 5-1/2" black vinyl	X373	
	Knob, 1-1/2" with pointer	X234	
	Receptacle, UHF	X403	
	Shield, 7 pin short-miniature type	X65	
	Shield, 9 pin type	X69	

USE CODE EFFECTIVITY

The following list of "Use Codes" is intended to allow the customer to determine the effectivity of all replaceable parts. All parts with no code are used on all instruments with serial numbers above 123. New codes will be added as necessary on forthcoming instruments.

USE CODE	EFFECTIVITY
No Code	Model 910A serial number 123 and on Model 910AR serial number 123 and on
*	Optimum value selected at factory. Average value is shown. Part may be omitted.
A	Model 910A serial number 123 thru 353 Model 910AR serial number 123 thru 178
B	Model 910A serial number 353 and on Model 910AR serial number 178 and on

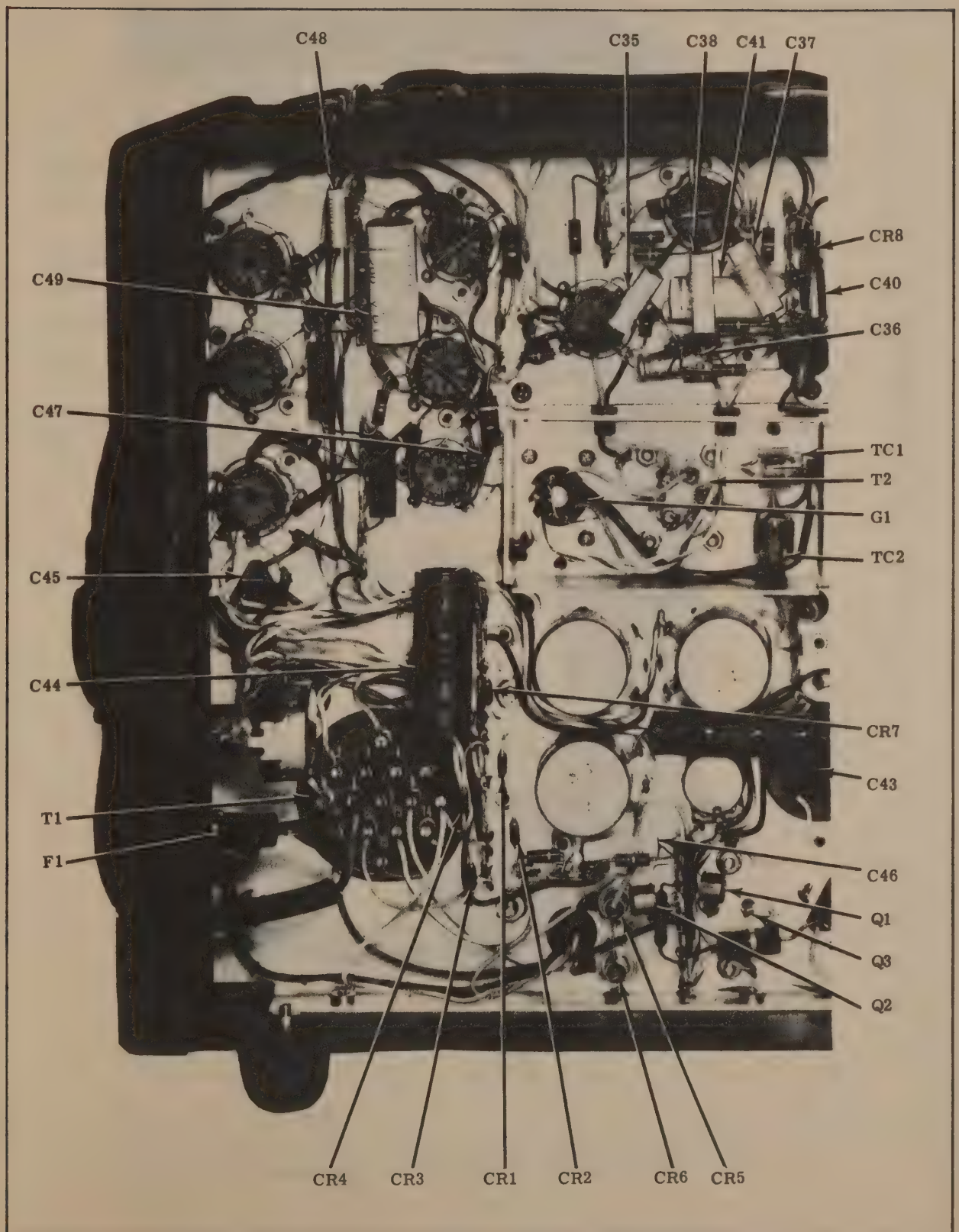


Figure 5-1. COMPONENT LOCATION, LEFT HAND SIDE (Sheet 1 of 4)

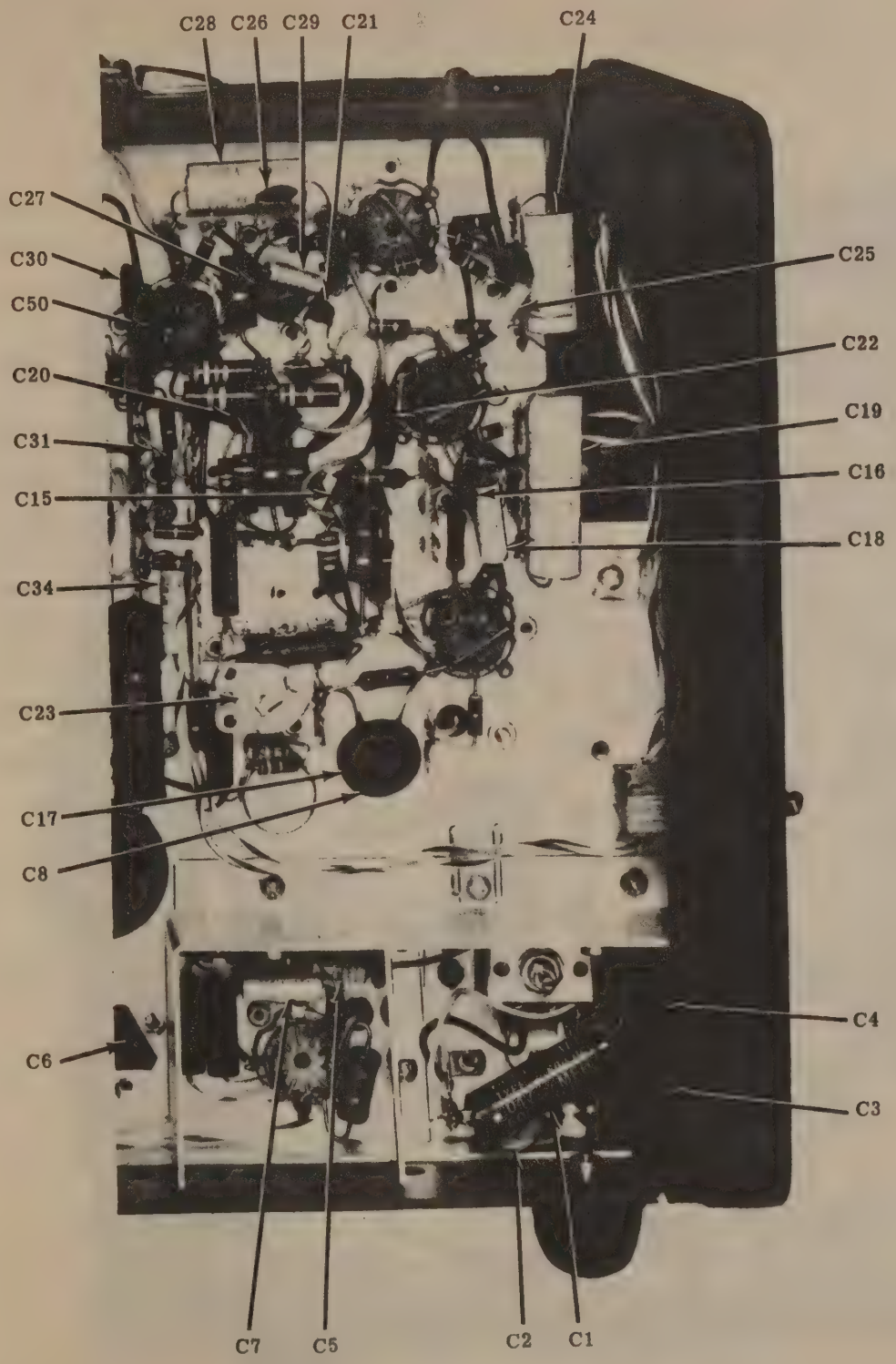


Figure 5-1. COMPONENT LOCATION, LEFT HAND SIDE (Sheet 2 of 4)

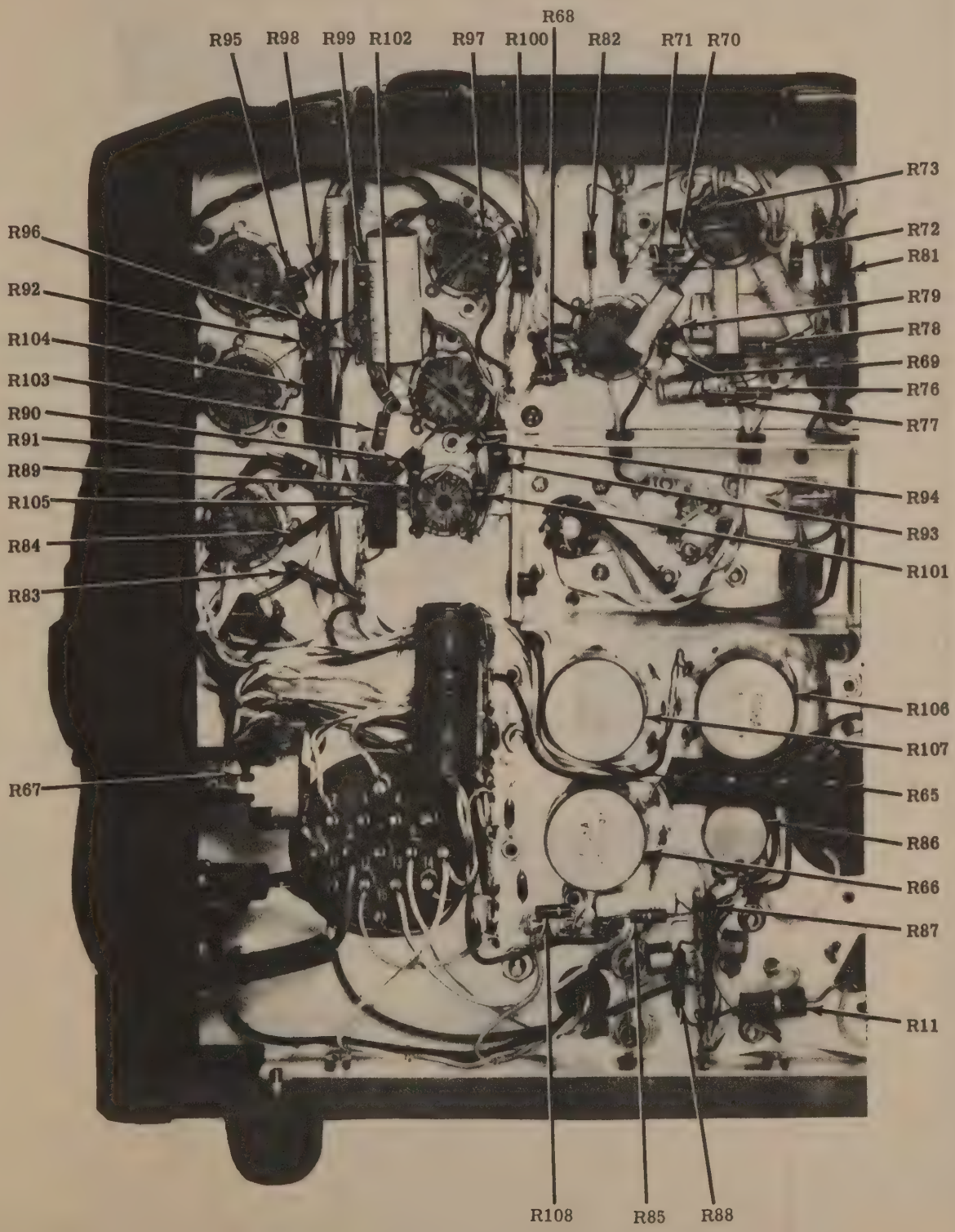


Figure 5-1. COMPONENT LOCATION, LEFT HAND SIDE (Sheet 3 of 4)

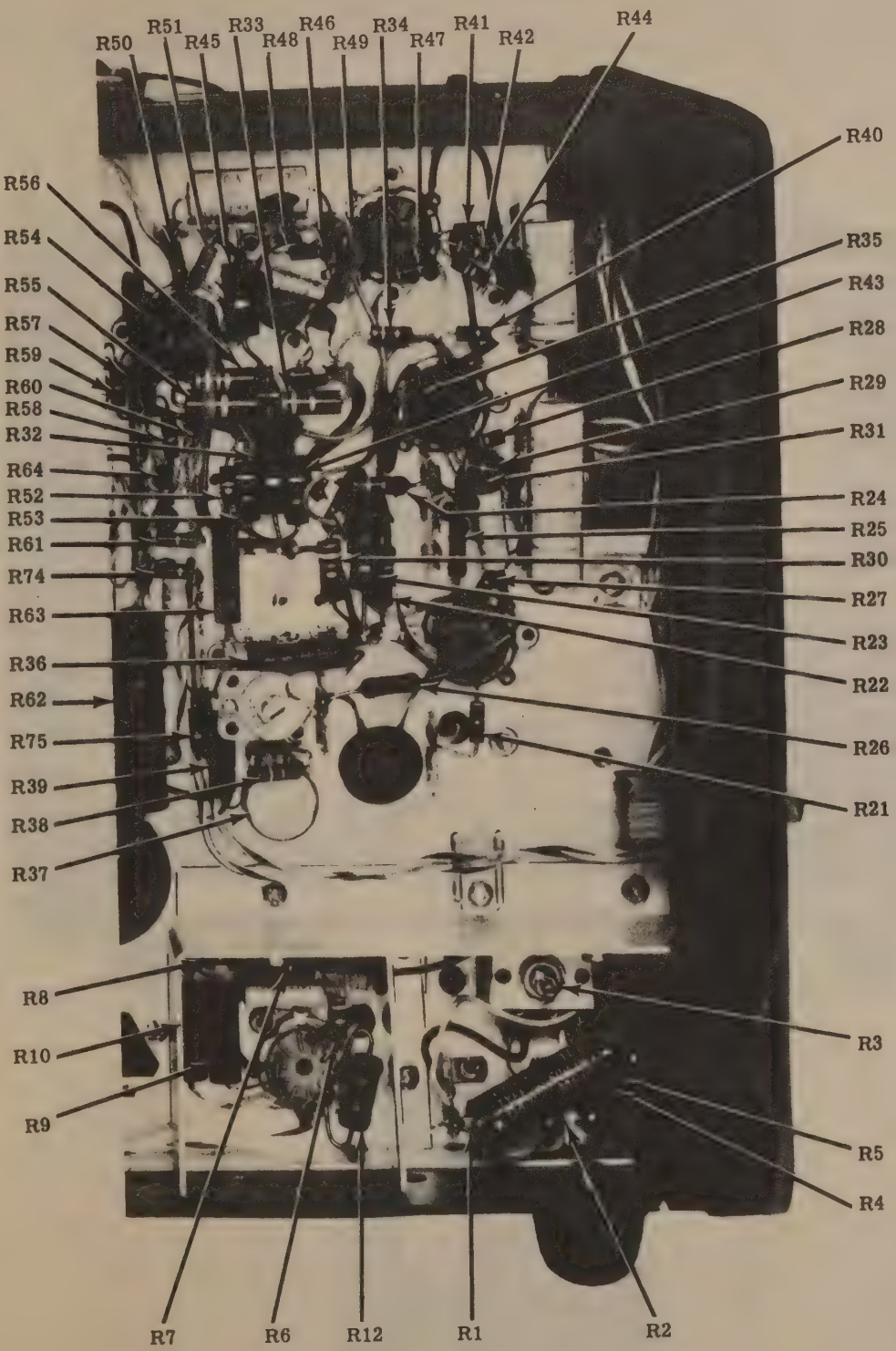
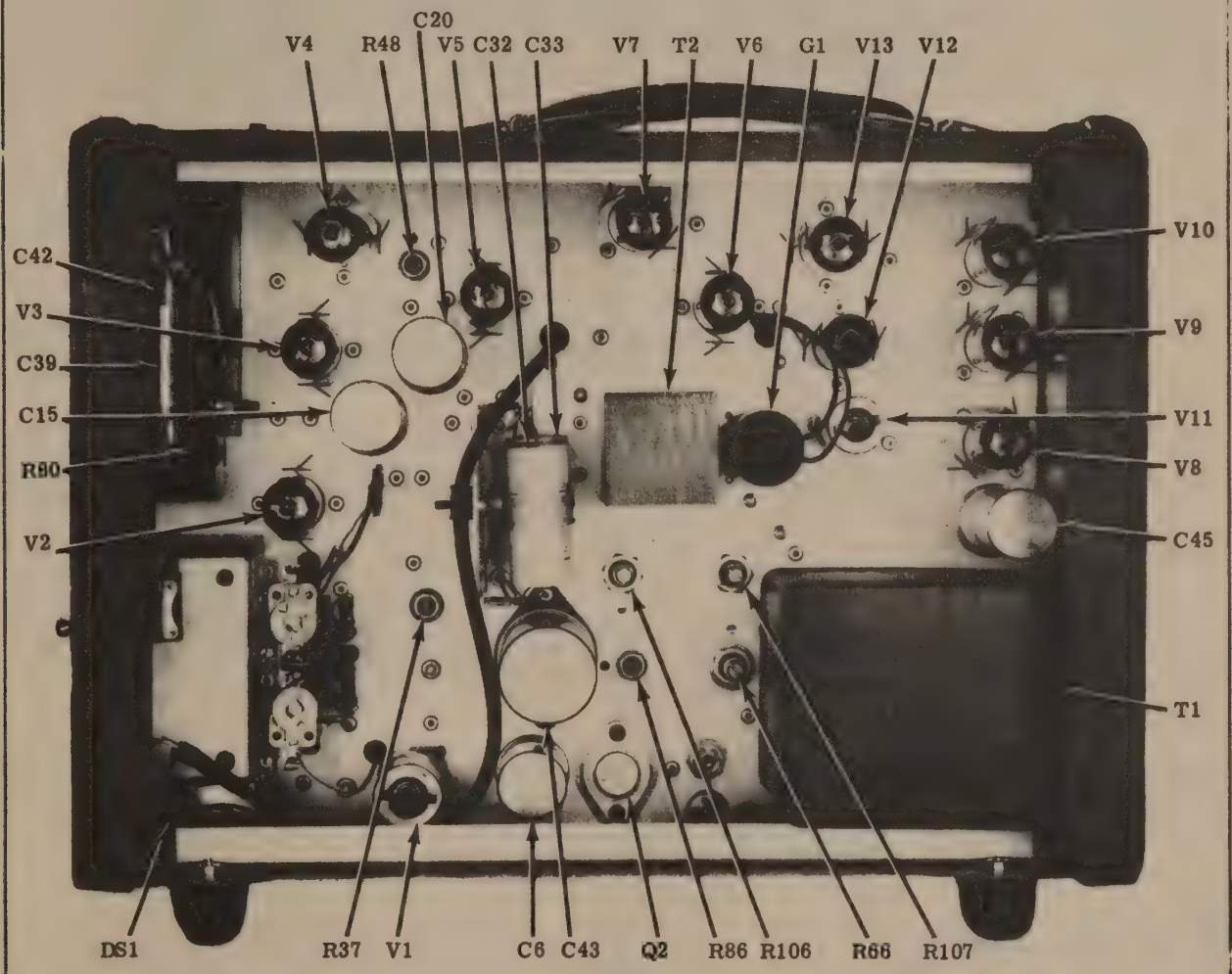
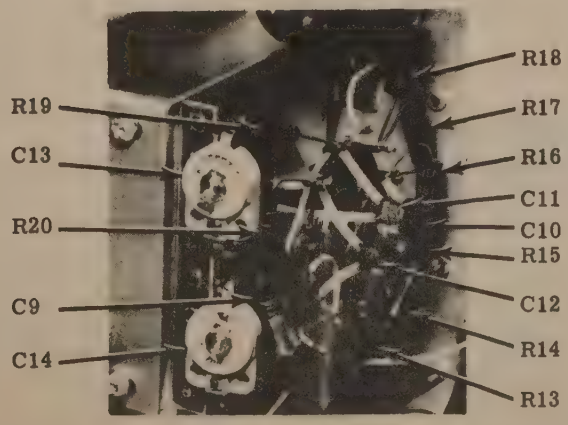
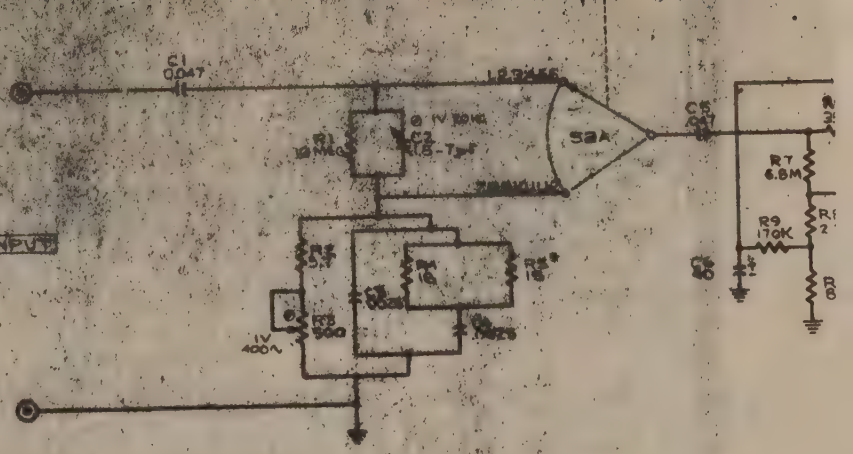
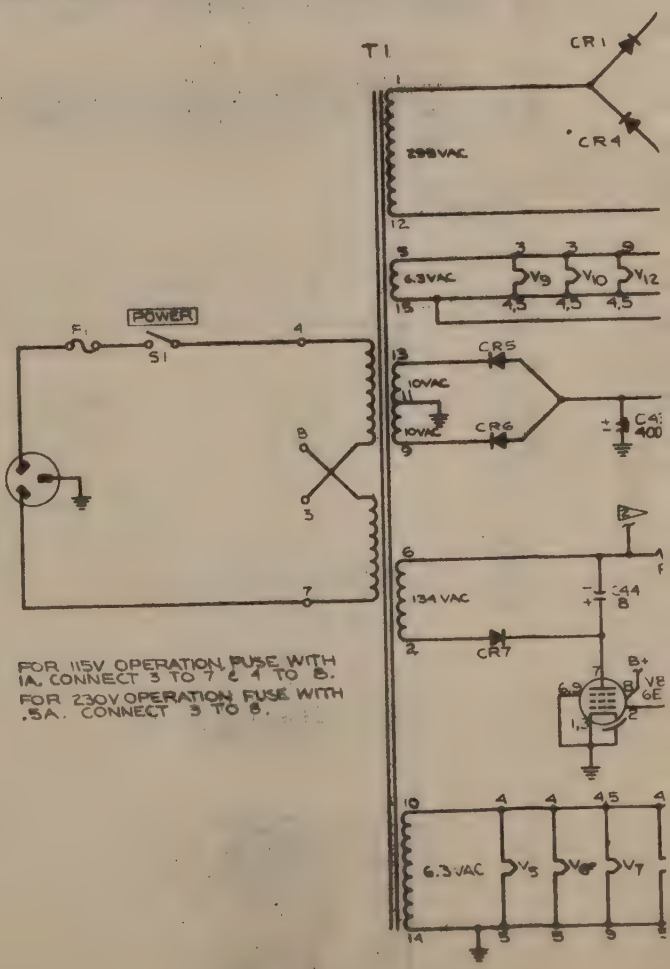


Figure 5-1. COMPONENT LOCATION, LEFT HAND SIDE (Sheet 4 of 4)

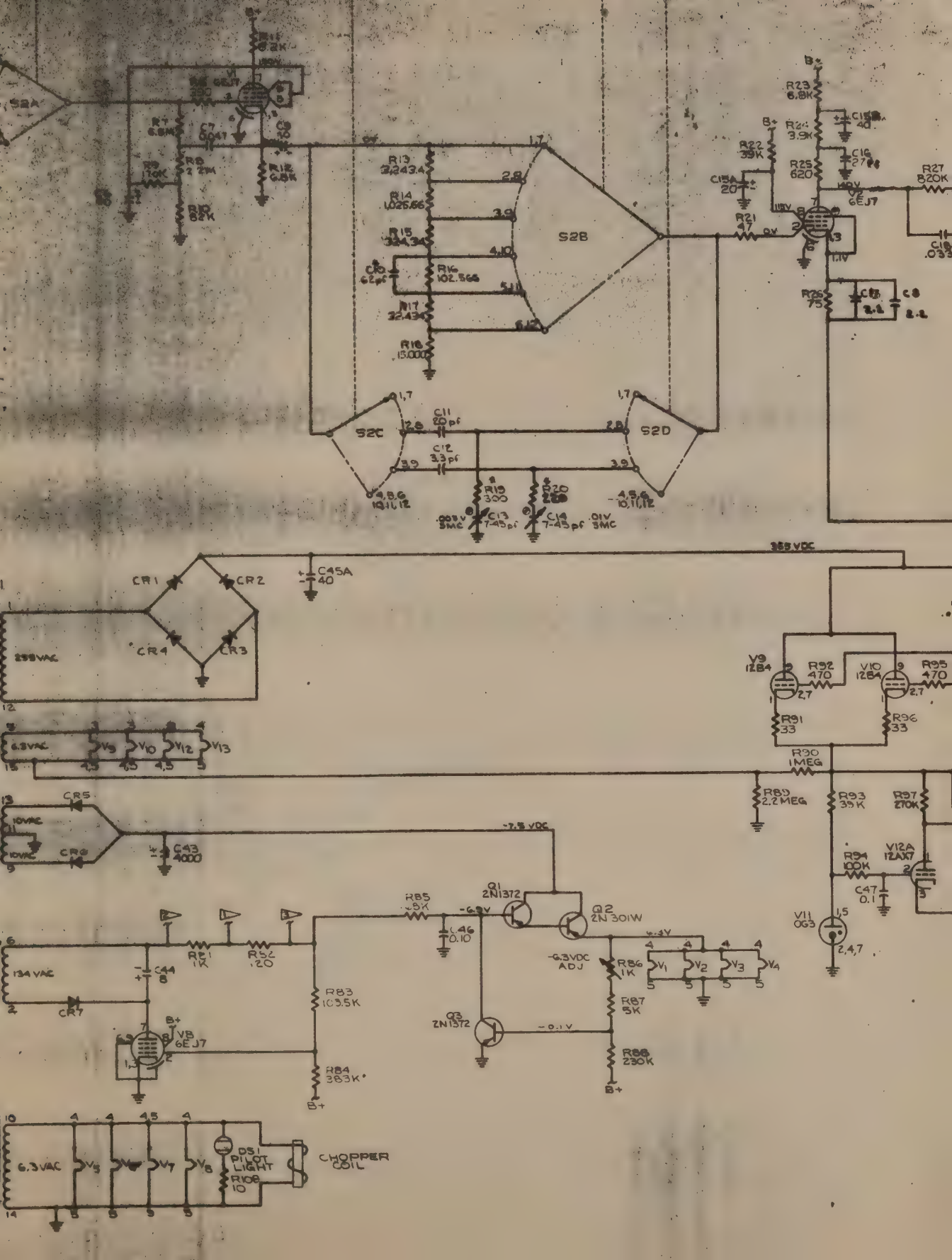

C20
V4
R48
V5
C32
C33
V7
T2
V6
G1
V13
V12
V10
C42
V3
V9
C39
C15
V11
R90
V8
V2
C45
T1
DS1
R37
V1
C6
C43
Q2
R86
R106
R66
R107

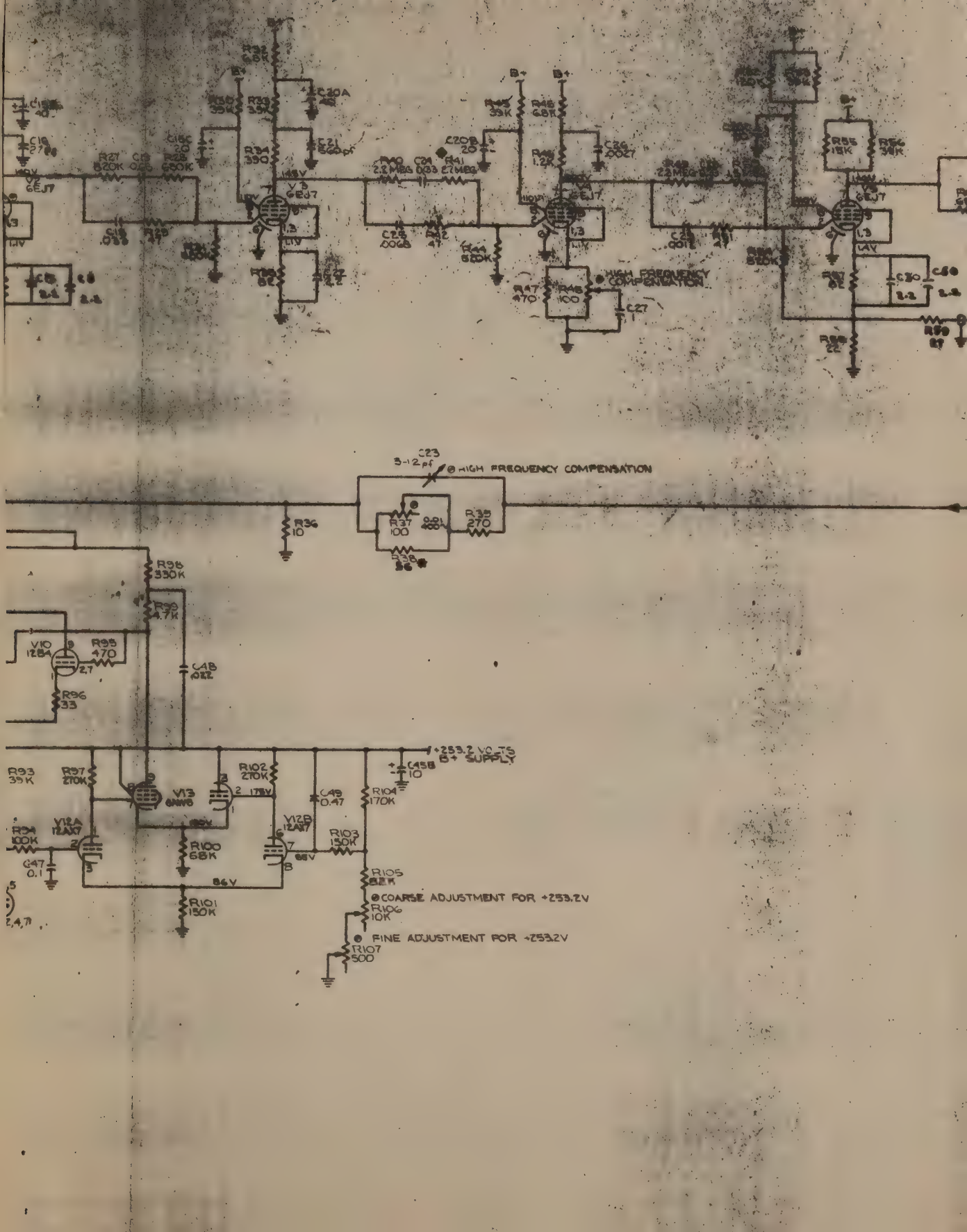

R18
R19
R17
C13
R16
C11
R20
C10
R15
C9
C12
R14
C14
R13

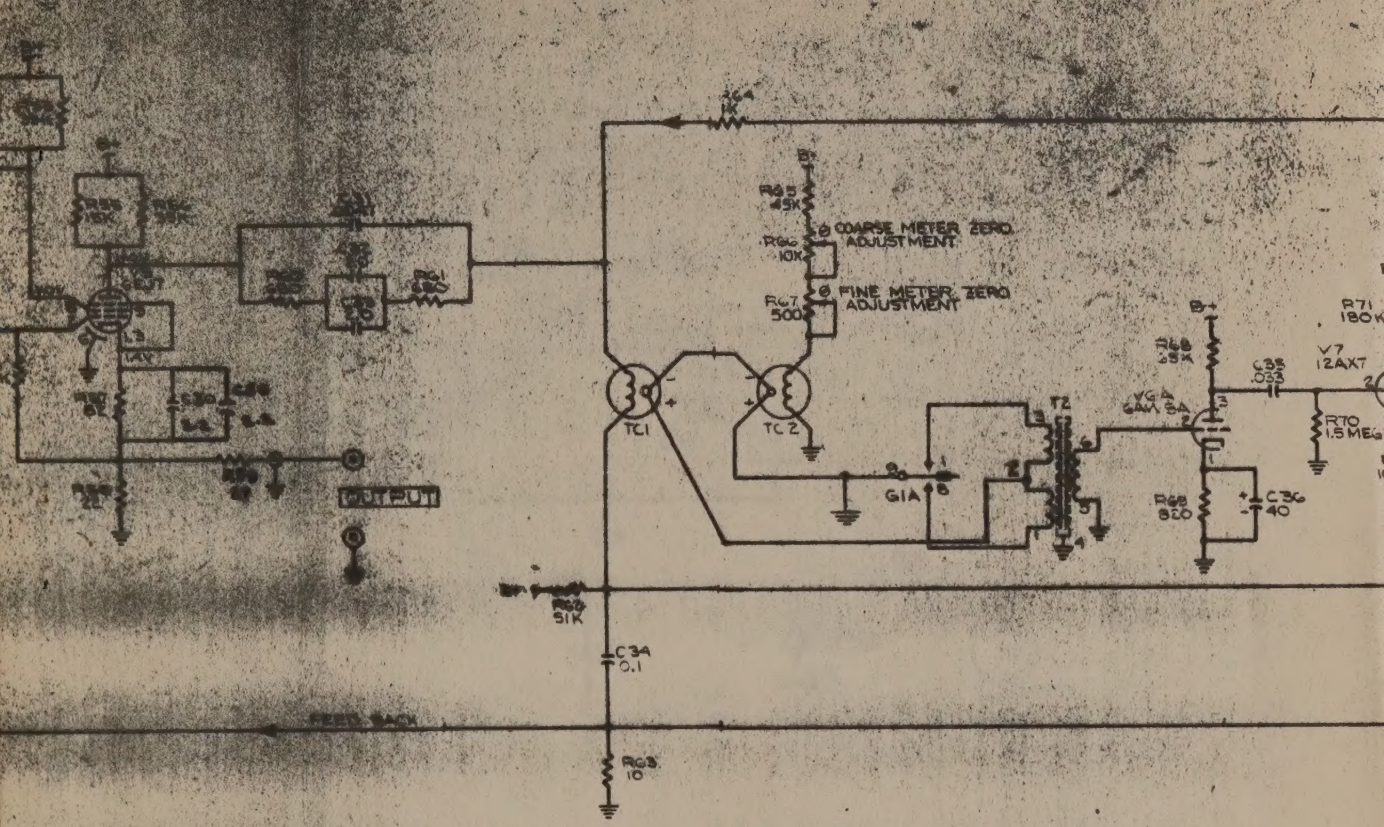




FOR 115V OPERATION FUSE WITH 1A. CONNECT 3 TO 7 & 4 TO 8.
FOR 230V OPERATION FUSE WITH .5A. CONNECT 3 TO 8.


S2A
S2B
S2C
S2D
R11 6.2K
R7 6.8M
C7 .0047
C9 10
R9 10K
R8 2.2M
R12 6.8K
R10 82K
R13 2,243.4
R14 1,026.66
R15 324.34
R16 102.566
R17 32.434
R18 15,000
C10 62pf
C11 20pf
C12 3.3pf
R19 300
R20 265
C13 7-45pf
C14 7-45pf
.005V SMC
.01V SMC
R23 6.8K
R24 3.9K
R22 39K
R25 620
C15A 20
C16 27pf
R27 820K
C18 .033
R21 47
C17 2.2
C8 2.2
CR1
CR2
CR3
CR4
C45A 40
298VAC
6.3VAC
V9
V10
V12
V13
CR5
CR6
10VAC
C43 4000
-7.5 VDC
Q1 2N1372
Q2 2N301W
Q3 2N1372
R85 .5K
C46 0.10
-6.3VDC ADJ
R86 1K
R87 5K
R88 230K
R81 1K
R82 120
R83 103.5K
R84 383K
C44 8
134 VAC
CR7
V8 6EJ7
V1
V2
V3
V4
385 VDC
V9 12B4
V10 12B4
R92 470
R95 470
R91 33
R96 33
R90 1MEG
R89 2.2MEG
R93 39K
R97 270K
R94 100K
V12A 12AX7
C47 0.1
V11 0G3
DS1 PILOT LIGHT
R108 10
CHOPPER COIL


C23
3-12 pf
HIGH FREQUENCY COMPENSATION
R36
10
R37
100
R35
270
R38
86
R98
330K
R99
4.7K
V10
12BH7
R95
470
2.7
C48
.022
R96
33
+253.2 VOLTS
B+ SUPPLY
R93
39K
R97
270K
V13
6HW8
R102
270K
C49
0.47
R104
170K
C45B
10
V12A
12AX7
R94
100K
C47
0.1
R100
68K
V12B
12AX7
R103
150K
R105
82K
COARSE ADJUSTMENT FOR +253.2V
R106
10K
FINE ADJUSTMENT FOR +253.2V
R107
500
R101
150K



ALL
NUMB

LAST NUMBERS USED

C50	S3
CR8	T2
DS1	TC2
F1	V13
S11	
TO3	
R108	

NOTES:

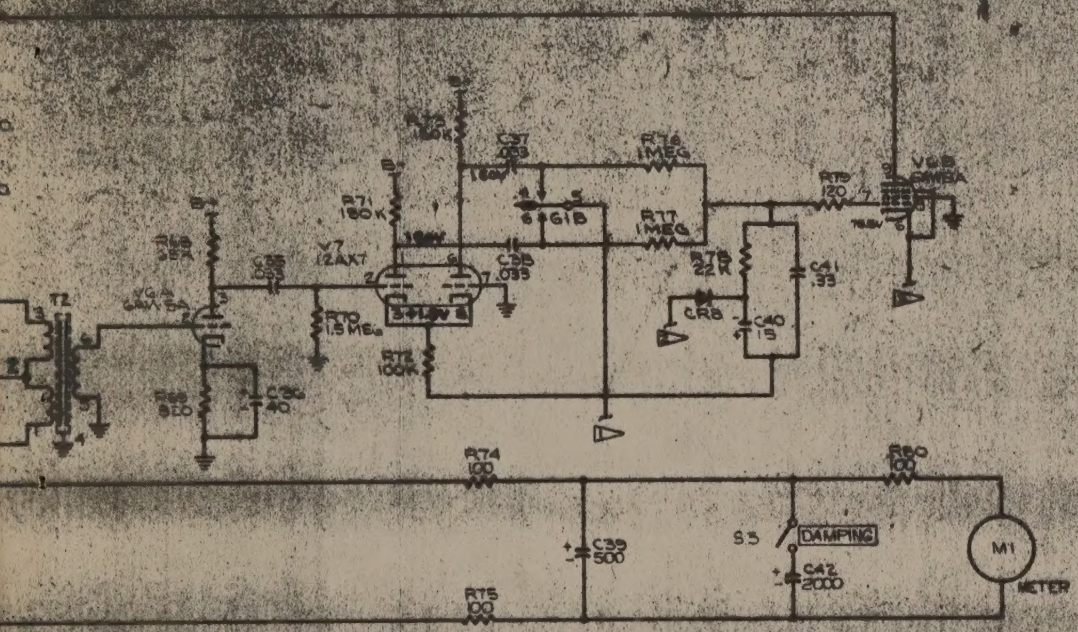
* OPTIMUM VALU
AVERAGE VA
PART MAY BE

RESISTANCE

CAPACITANCE
OTHERWISE

VOLTAGES D
Ω MEG OR G

RANGE SW
LINE. OV IN



▷ ▷ ▷ } ALL FLAGNOTE WITH SAME NUMBER ARE CONNECTED.

NOTES:

OPTIMUM VALUE SELECTED AT FACTORY AVERAGE VALUE SHOWN PART MAY BE OMITTED

RESISTANCE IN OHMS

CAPACITANCE IN MICROFARADS UNLESS OTHERWISE NOTED.

VOLTAGES DC MEASURED WITH VTVM 10 MEG OR GREATER INPUT RESISTANCE.

RANGE SW IN 300V POSITION 115VAC LINE, 0V INPUT.

910A SER.NO. 4231 ABOVE

910AR SER. NO. 2181 ABOVE

FUNCTIONAL SCHEMATIC

RMS VOLTMETER

MODEL 910A/AR

JOHN FLUKE MANUFACTURING COMPANY
MOUNTLAKE TERRACE, WASHINGTON